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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : G03B 21/62, 21/60

A2

(11) International Publication Number: WO 99/53376

(43) International Publication Date: 21 October 1999 (21.10.99)

(21) International Application Number: PCT/US99/07785

(22) International Filing Date: 9 April 1999 (09.04.99)

(30) Priority Data:
60/081,217 9 April 1998 (09.04.98) US

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(81) Designated States: JP, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

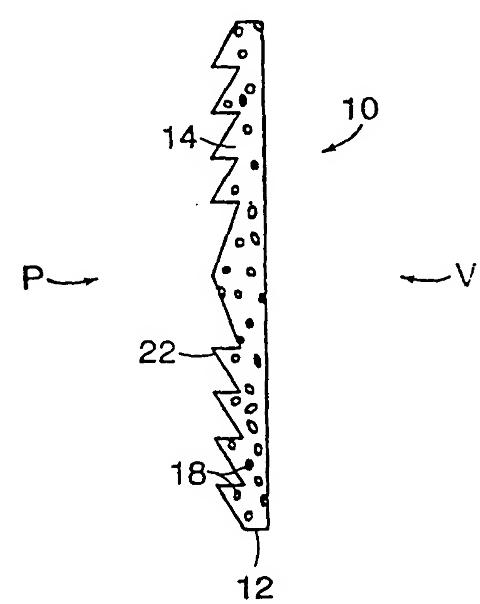
Published

Without international search report and to be republished upon receipt of that report.

(54) Title: PROJECTION SCREEN ASSEMBLIES

(57) Abstract

A rear projection screen assembly is disclosed which includes a single-sided Fresnel layer. The Fresnel layer includes a Fresnel structure on one side of the Fresnel layer, a matrix, and a plurality of particles embedded within the matrix, the plurality of particles having a refractive index different from the refractive index of the matrix, and imparting light-diffusing characteristics to the Fresnel layer.



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PROJECTION SCREEN ASSEMBLIES

Related Application

This application claims the benefit of copending U.S. Provisional Patent Application Serial No. 60/081,217, filed April 9, 1998, the entire disclosure of which is incorporated by reference herein.

Field of the Invention

The invention relates generally to projection screen assemblies and systems. More specifically, the invention relates to rear projection screen assemblies with improved stability and contrast.

Background of the Invention

Generally, projection screen assemblies which incorporate Fresnel lenses exhibit undesirable changes in focal length because typically over the course of time, the Fresnel lens layer will bow and/or displace out of the projection screen assembly. Bowing or deformation of the Fresnel lens changes the focal length of lens across the surface of the assembly which results in a blurred image. Of course, if the Fresnel lens is displaced out of the screen assembly, the projection screen assembly will not operate as designed.

Projections screens also suffer from a loss in contrast due to the reflection and refraction of ambient light upon the projection screen and due to an image artifact known as ghosting. Ghosting often is attributed to both the internal reflection of light at the Fresnel facet-air interface and a differential between the focal length of the Fresnel lens and the focal length of the light diffusing layer. Attempts have been made to compensate for ghosting by manipulating the design of the Fresnel facets. For example, by rendering opaque the portion of the facet perpendicular to the Fresnel lens (referred to as riser facets) incident light is absorbed. Also, the focal length of the Fresnel lens may be manipulated. However, these modifications typically result in a loss of other desired characteristics, such as brightness and resolution due to increased focal length and increased absorption of light.

There exists a need for a projection screen assembly and system with increased stability and which compensates for or eliminates ghosting and the reflection of ambient light without a loss in resolution or brightness.

Summary of the Invention

A rear projection screen assembly and system have been developed that exhibits increased stability and which compensates for or eliminates ghosting and the reflection of ambient light without a loss in resolution or brightness.

The rear projection screen assembly of the present invention generally includes a single-sided Fresnel layer which includes a matrix and a Fresnel structure on one side of the Fresnel layer. The matrix includes a plurality of particles embedded within the matrix, which particles have a refractive index different from the refractive index of the matrix.

The rear projection screen system of the present invention generally includes the rear projection screen assembly of the present invention and a projection source. Rear projection systems suitable for use in accordance with the present invention include rear projection movie screens, televisions, including large screen televisions, and computer projection monitors including large screen computer monitors.

The invention will be understood further upon consideration of the following drawings, description and claims.

Description Of The Drawings

Note that the drawings are not necessarily to scale, but rather emphasize illustration of the concepts and principles of the invention. The invention may be better understood by reference to the description taken in conjunction with the accompanying drawings, in which:

Figure 1 is a schematic cross-sectional side view of an embodiment of a screen assembly in accordance with the present invention;

Figure 2 is a schematic cross-sectional side view of an another embodiment of a screen assembly in accordance with the present invention; and

Figure 3 is a schematic cross-sectional side view of yet another embodiment of a screen assembly in accordance with the present invention.

Like reference characters in the respective drawn figures indicate corresponding parts.

Detailed Description Of The Invention

In general, and referring to Figure 1, the rear projection screen assembly 10 disclosed herein includes a single-sided Fresnel layer 12 which includes a Fresnel structure 22 on one side of the Fresnel layer 12, a matrix 14 having a plurality of particles 18 embedded within the matrix 14. The plurality of particles 18 embedded in the matrix 14 have a refractive index different from that of the matrix, thereby imparting light-dispersing characteristics to the Fresnel layer 10.

"Single-sided Fresnel layer" means a Fresnel layer having one or more Fresnel structures on only one side of the Fresnel layer, as opposed to a double-sided Fresnel layer which has Fresnel structures on both sides of the Fresnel layer.

In use, the Fresnel layer 12 has a projection source side, indicated by the arrow emanating from the letter P, and a viewing side indicated by the arrow emanating from the letter V. The Fresnel structure 22 may be on either the projection source side P or the viewing side V. Preferably, the Fresnel structure 22 is on the projection source side of the Fresnel layer 22 as shown in Figure 1.

The Fresnel layer of the present invention combines the light-dispersing properties of a bulk diffusion layer with the light-collimating properties of a Fresnel structure. This combination results in a screen assembly which has several advantages over the prior art.

One advantage is that since both layers are combined, the screen assembly is thinner. Thinner screen assemblies are desirable because they typically have improved resolution properties and also because they allow for smaller projection systems.

Another advantage of the Fresnel layer of the present invention is increased stability. The Fresnel layer is less likely to bow, deform or displace out of the screen assembly when combined with the diffusion layer. That is, typically a Fresnel lens and diffusion screen are held together by mounting brackets. The mounting brackets apply pressure to the layers about the periphery of the screen assembly tending to create a bow in the Fresnel layer over time which imparts a focal length variation across the plane of the screen resulting in a blurred and/or distorted image. In addition, image distortion problems associated with the vibration of the Fresnel lens are also reduced or eliminated due to the increased stability of the Fresnel layer

Yet another advantage of the Fresnel layer of the present invention is the elimination of a ghosting effect which occurs when the Fresnel lens and the light-dispersing layer are separate. Without wishing to be confined to any particular theory, it is believed that a ghosting effect occurs as a result of a mismatch between the focal length of the Fresnel lens and the focal length of the light-dispersing layer. The Fresnel layer of the present invention, which combines the Fresnel lens with the light-dispersing layer, does not exhibit this ghosting effect. Note that it is believed that the ghosting effect which occurs due the presence of a separate Fresnel lens and light-dispersing layer is different from the ghosting effect which is believed to occur as a result of internal reflection at the Fresnel facet-air interface. The latter ghosting effect may be corrected by an another embodiment of the present invention discussed below.

Still yet another advantage of the present invention is that the embedded diffusion particles reduce the loss of brightness which may occur at or near the corners of the Fresnel structure due to internal reflection. It is known that a loss of brightness often occurs at or near the edges of a Fresnel lens, particularly in large screen assemblies, due to internal reflection of light incident to the Fresnel facets at or near the Fresnel lens periphery. The diffusion characteristics of the Fresnel layer of the invention compensates for this loss of brightness.

The matrix material preferably is durable, stable, and allows adhesion or lamination to other materials, such as a contrast enhancement layer or a support layer. Suitable matrix materials for use in accordance with the present invention include, among others, acrylics, such as polymethylmethacrylates and polyethylethylacrylates; polyesters; polystyrenes; polyolefins, such as polyethylenes, polypropylenes, and their copolymers; polyamides; organic acid cellulose esters, such as cellulose acetate butyrates, cellulose acetates, and cellulose acetate propionates; polycarbonates; and combinations thereof. In a preferred embodiment, the matrix is a polypropylene/polyethylene copolymer. In another preferred embodiment the matrix is ethylethylacrylate. In yet another preferred embodiment, the matrix is polyethylene.

The matrix also may include appropriate compatibilizers to improve the processing and performance of a Fresnel layer of the present invention. These compatibilizers are described in greater detail in pending U.S. Patent Application Serial No. 08/962,743, filed November 3, 1997, which is incorporated herein by reference.

Suitable materials for use as the embedded particles include, among others, acrylics, such as polymethylacrylates; polystyrenes; polypropylenes; organic acid cellulose esters, such as cellulose acetate butyrates, cellulose acetates, and cellulose acetate propionates; polycarbonates; and combinations thereof. In a preferred embodiment, polystryrene is used. Suitable acrylics include cross-linked acrylics, such as the so-called "core-shell" cross-linked acrylic polymers manufactured by Rohm and Haas Company (Philadelphia, Pennsylvania).

One combination of a matrix and embedded particle materials useful in the present invention is ethylethylacrylate as the matrix material and polystyrene as the embedded particle material. Another combination useful in the present invention is polyethylene as the matrix material and polystyrene as the embedded material.

The embedded materials may be spherical or elliptical in shape. However, depending on the method of manufacture, both shapes of particles may be present in the matrix.

Embedded ellipsoidal particles typically are all oriented with their major axes substantially in one direction in the plane of the surface of the Fresnel layer. Preferably, the ellipsoidal particles are made from a material which is capable of being deformed at a processing temperature in order to create their ellipsoidal shape by stretching. Further, the volume density of the particles, the average ellipsoidal particle minor axis size, and the index of refraction the ellipsoidal particles may be optimized to control the desired properties of the Fresnel layer, such as horizontal viewing angle.

The average particle size of the ellipsoidal particles in the matrix may be from about 1 micrometer (μm) to about 30 μm, preferably from about 2 μm to about 15μm, and most preferably from about 2 μm to about 5 μm in the minor dimension.

Embedded spheroidal particles preferably are substantially incapable of deformation at the processing temperature so that they remain substantially spheroidal throughout the formation of the Fresnel layer, which optionally includes ellipsoidal particles. The volume density and the average particle size may be optimized to control the desired properties of the material, for example, to minimize or eliminate scintillation.

The average particle size of the spheroidal particles in the matrix may be from about 1 micrometer (μm) to about 30 μm, preferably from about 5 μm to about 30μm, and most preferably from about 10 μm to about 30 μm.

The differential refractive index (Δn_{ME}) defined as the absolute value of the difference between the index of refraction of the matrix (n_M) and the index of refraction of the particles (n_E), or $|n_M - n_E|$, may be from about 0.005 to about 0.2, and preferably is from about 0.007 to about 0.1.

The embedded particles may comprise from about 2% to about 45% of the Fresnel layer by volume, and preferably from about 5% to about 30% of the Fresnel layer by volume.

Optionally, the Fresnel layer may further include an antireflective coating disposed on the Fresnel structure. Antireflective coatings and their application to surfaces are well known in the art.

A suitable processing temperature for forming embedded ellipsoidal particles may be determined from the glass transition temperature and melt temperature of the ellipsoidal particle material used and the amount of deformation desired. A processing temperature approaching or close to the glass transition temperature will result in less deformation than a processing temperature approaching or surpassing the melt temperature, with all other variables including the amount the material is stretched, remaining the same.

A method for forming a Fresnel layer having both spheroidal and elliptical particles embedded in the matrix material includes: selecting a matrix material, a first particle material which is capable of deformation at a process temperature, and a second particle material which is substantially incapable of deformation at the process temperature; dispersing the first particle material and the second particle material in the matrix to form a mixture comprising the matrix, the first particle material and the second particle material; forming a sheet of material from the mixture; stretching the sheet of material at the processing temperature along an axis in the plane of the sheet of material such that the first particle material is deformed along the direction of stress; and forming the Fresnel structure on one side of the sheet of material. The process of may further include the step of heating the mixture to the processing temperature prior to forming the sheet or prior to stretching the sheet

A sheet of desired thickness may be formed by extruding the mixture through a die. Another option is to form the sheet by pouring the mixture onto a flat surface.

To produce embedded ellipsoidal particles, the sheet may be stretched as it exits from a die by winding the sheet of material on a take-up roll at a rate faster than the sheet formation rate. If the sheet is stretched at the processing temperature, the first dispersion material will be deformed in the direction along which it is stretched. Alternatively, the sheet may be stretched upon a frame at the processing temperature in order to deform the first dispersion material. Provided the sheet is stretched to a greater degree in one direction, the ellipsoidal particles will be oriented in that direction.

The Fresnel structure may be formed on the Fresnel layer using a variety of techniques well known in the art including microreplication of the Fresnel facets using thermoembossing techniques.

It should be understood that the order of the steps for making the Fresnel layer is immaterial except that the mixture needs to be formed prior to further processing, i.e., e.g., forming a sheet, heating, stretching, extruding, and/or winding. Furthermore, if ellipsoidal particles are desired, they typically are formed prior to formation of the Fresnel structure. In addition, two or more of the steps described above may be conducted simultaneously.

Figure 2 is a schematic cross-sectional side view of another embodiment of the present invention in which the screen assembly 10 includes a contrast enhancement layer 26. In general overview, the screen assembly 10 includes a Fresnel layer 12 which comprises a matrix 14, embedded particles 18, and a Fresnel lens structure 22 formed on the surface of the Fresnel lens layer 12. Preferably, the contrast enhancement layer 26 is on the projection source side of the Fresnel layer 22, indicated by the arrow emanating from the letter P. The depicted assembly also includes a support layer 30.

One advantage of this embodiment is that the contrast enhancement layer absorbs ghosting light rays exiting from the Fresnel layer. Because Fresnel structures are dentate, or tooth-like, a ghosting effect may and often does occur as a result of internal reflection at the Fresnel facet-air interface. Internal reflection of light rays from the projection source produces one or more images slightly offset from the primary image. Without wishing to be confined to any particular theory, it is thought that these offset images are due to the extra distance along the Fresnel

structure that the light rays must travel as a result of internal reflection. These offset images are visible to the viewer as secondary or ghost-like images of the primary image, hence the term, "ghosting."

Traditional approaches to solving the problem of ghosting have focused on optimizing the Fresnel lens through the manipulation of the facet design. For example, a lenticular array may be added to the surface of the facets to diffuse the image and thus make the ghost-like image less noticeable. However, these design changes merely mask the secondary image(s). In addition, the Fresnel lenses with a lenticular array typically are prohibitively expensive to produce.

It has been discovered that the addition of a contrast enhancing layer adjacent to the Fresnel layer may be used to reduce and even eliminate the ghosting effect which occurs as a result of internal reflection at the Fresnel facet-air interface.

Another advantage of this embodiment of the invention is that the contrast enhancing layer adjacent to the screen further reduces the reflection of ambient light incident to the screen assembly from the viewing side of the screen assembly thereby further improving the contrast of the projected image.

The contrast enhancement layer may be any of a variety of contrast enhancement layers known in the art including a tint layer, a polarizing layer, or a microlouver layer. In one embodiment of the present invention, the contrast enhancement layer is a tint layer. A tint layer reduces the reflection of ambient light by absorption of light incident to its surface. Similarly, it will absorb ghosting light rays from the Fresnel layer.

In another embodiment, the projection light source is polarized and the contrast enhancement layer is a polarizing layer. Preferably, the type of polarized light is matched to the type of polarizing layer. For example, a linear light source is matched with a linear polarizer, a circularly polarized light source with a circular polarizer, an elliptically polarized light source with an elliptical polarizer, and so forth. The polarizing layer enhances the contrast of the projected image by filtering out secondary or ghost light rays incident to its surface which are not traveling in the polarized direction of the polarizer layer while allowing the primary image to pass through the polarizer layer. One example of a polarizing layer suitable for use with the present invention is the LC™ Polarizer manufactured by Optiva, Inc. (San Mateo, California), which is a liquid crystalline composite material capable of direct application to a substrate. Such a polarizing layer

may be directly applied to the surface of the Fresnel layer or to a surface of an optional support layer.

In yet another embodiment of the present invention, the contrast enhancement layer is a microlouver layer. A microlouver layer is an angularly selective filter, operating much like a venetian blind, which allows incident light at selected angles to pass through the layer to the viewing side of the assembly while absorbing the rays incident to the layer at unselected angles. The microlouver is selected to allow the projected image to pass through while absorbing light incident to the microlouver at an angle offset from the preferred angle, including ghosting light rays. Further, the microlouver layer will reduce the reflection of ambient light by absorbing the ambient light incident on its surface outside of the selected range of angles thereby further increasing the contrast of the projected image. A microlouver layer suitable for use in the present invention is that manufactured by 3M (Minnesota, United States). Another microlouver layer suitable for use in the present invention is NPF F1029DU manufactured by Nitto Denko (Japan).

Optionally, the contrast enhancement layer may include a matte finish on its viewing side. The contrast enhancement layer may further include as an alternative to the matte finish or in addition thereto, an antireflective coating on its viewing side. The matte finish and the antireflective coating reduce glare due to the reflection of ambient light.

The optional support layer 30 shown in Figure 2 may comprise any transmissive material which will impart structural stability to the assembly, such as, for example, acrylic or glass. The support layer also may be included to protect the contrast enhancement layer against scratching or scuffing. The support layer may be optionally coated with an antireflective coating or include a matte finish on the viewing side of the support layer in order to decrease reflection of ambient light.

Figure 3 is a schematic cross-sectional side view of yet another embodiment of a screen assembly 10 constructed in accordance with the present invention. In general overview, the screen assembly 10 includes a Fresnel layer 12 which comprises a matrix 14, embedded particles 18, and a Fresnel lens structure 22 formed on the surface of the Fresnel lens layer 12. The assembly 10 also includes a contrast enhancement layer 26 and a support layer 30.

The Fresnel structure 22 has a centerline A which is off set from the centerline B of the assembly 10 by a distance "ℓ" in order to effect an off-axis tilt to the projected image. The off-axis tilt serves to correct keystone distortion which occurs when light is not projected to the screen assembly an angle normal to the screen assembly. As a result, one end of the image appears stretched out while the other is condensed. Typical approaches to solving keystone distortion include pre-distortion of the projected image to compensate for the keystone distortion. The off-axis tilt of the present invention provides a simple and inexpensive solution to keystone distortion.

The screen assembly of the present invention may be constructed by adhering the Fresnel layer to the contrast enhancement layer by the application of a clear adhesive to one or both surfaces of these layers which contact each other. Similarly, any optional layers may be adhered to other assembly layers by the application of a clear adhesive. Alternatively, because the Fresnel layer of the invention imparts improved stability to the Fresnel focal length the assembly be constructed by mounting the Fresnel layer and the contrast enhancement layer in mounting brackets along the outer periphery of the assembly. Other optional layers may be similarly mounted with mounting brackets.

The screen assemblies of the invention are useful in rear projection screen systems such as televisions, including large screen televisions, computer projection monitors, including large screen computer monitors, and rear projection motion picture screens. In addition to the screen assembly of the invention, a projection source is provided which projects images onto the projection source side of the screen assembly. Other features and structure of the screen system of the invention readily are known to skilled artisans and optionally may be included.

Although generally the preferred embodiments of the invention have been shown and described, numerous variations and alternative embodiments will occur to those skilled in the art. Accordingly, it is intended that the invention be limited only in terms of the appended claims as the invention may be embodied in other specific forms.

CLAIMS

What is claimed is:

1. A rear projection screen assembly comprising:

a single-sided Fresnel layer, the single-sided Fresnel layer comprising:

a matrix having a plurality of particles embedded within the matrix,

wherein the plurality of particles have a refractive index different from the refractive index of the matrix; and

a Fresnel structure on one side of the Fresnel layer.

2. The assembly of claim 1 wherein the Fresnel layer has a viewing side and a projection source side, the projection source side comprising the Fresnel structure.

3. The assembly of claim 1 further comprising an antireflective coating disposed on the Fresnel structure.

4. The assembly of claim 1 wherein the Fresnel layer comprises a microreplicated Fresnel structure thermoembossed into a surface of the Fresnel layer.

5. The assembly of claim 1 further comprising a contrast enhancement layer adjacent to the Fresnel layer.

6. The assembly of claim 5 wherein the Fresnel layer has a projection source side and a viewing side and the contrast enhancement layer is adjacent to the viewing source side of the Fresnel layer.

7. The assembly of claim 5 wherein the contrast enhancement layer is a tint layer.

8. The assembly of claim 5 wherein the contrast enhancement layer is a polarizing layer.

9. The assembly of claim 8 wherein the polarizing layer linearly polarizes light.

10. The assembly of claim 5 further comprising a microlouver layer.

11. The assembly of claim 5 wherein the contrast enhancement layer has a projection source side and a viewing side, wherein the viewing side comprises a matte finish.

12. The assembly of claim 5 wherein the contrast enhancement layer has a projection source side adjacent to the Fresnel layer and a viewing side, the viewing side comprising an antireflective layer.

13. The assembly of claim 1 further comprising a support layer.

14. The assembly of claim 13 wherein the support layer is acrylic.

15. The assembly of claim 13 wherein the support layer has a projection source side and a viewing side, the viewing side comprising a matte finish.

16. The assembly of claim 1 wherein the assembly has an assembly centerline and the Fresnel layer has a Fresnel layer centerline and the Fresnel layer centerline is offset from the assembly centerline.

17. A rear projection screen system comprising the assembly of claim 1, and
a projection source.

18. The rear projection screens system of claim 17 wherein the system is a computer projection monitor, a television screen, or a large format rear projection screen.

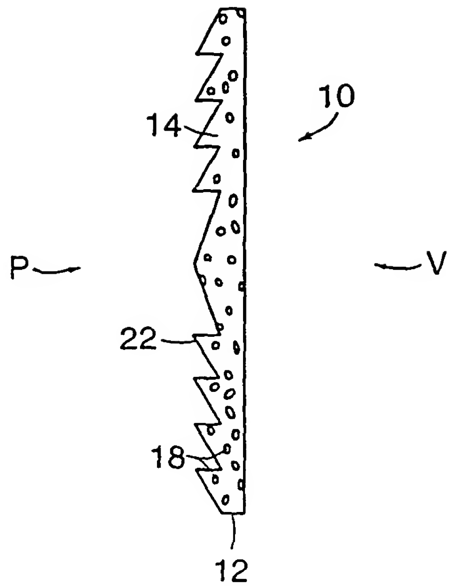

FIG. 1

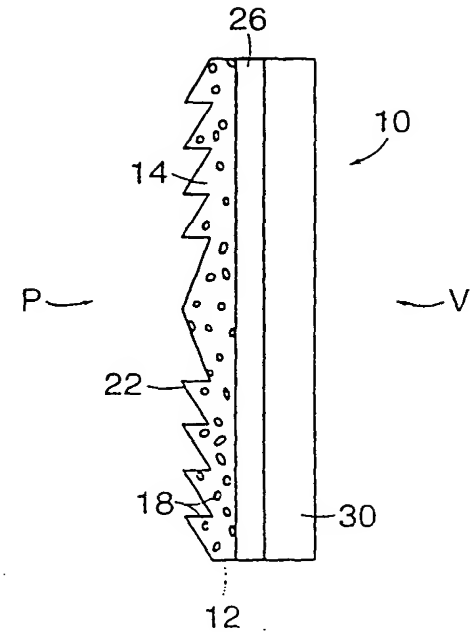

FIG. 2

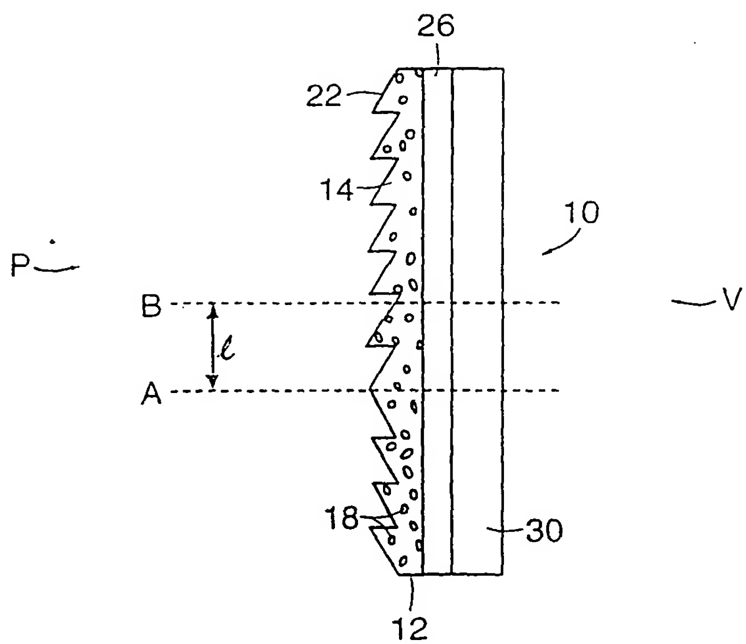

FIG. 3